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## AGASSIZ'S WORK ON FOSSIL FISHES.

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WHATEVER advances have been made in the science of paleichthyology since the time of Louis Agassiz, it is a significant fact that they have been rendered possible almost solely as the result of Agassiz's own researches. The position that Agassiz holds in the history of the science is that of founder, of extraordinarily acute and painstaking observer, of careful and sagacious systematist. If he was the first to place the study of paleichthyology upon a truly scientific basis, so, too, his contributions to this subject greatly preponderate over those of any other author. And not only was the knowledge of fossil fishes vastly increased by means of his writings, but, both directly and indirectly, he stimulated other investigators to pursue kindred lines of research.

It was especially fortunate that Agassiz should have been led to take up the study of fossil fishes when he did, for the reason that he possessed a more extensive knowledge of recent forms than probably any other savant in Europe with the exception of Cuvier, who unhappily did not live to see even the inception of the *Poissons Fossiles*; and also because there existed in the different museums at that time a large array of material, eminently suited for comparative investigation, and waiting only for a monographer. Without the wide experience in zoology and anatomy that Agassiz had already enjoyed, without his powers of penetration, of fine discrimination, and excellent judgment, it is safe to say that no one could have prepared a well-digested account of so much new material, nor have made clear the structure and relationships of such fragmentary remains. Genius, without training, could not have accomplished the masterwork which Agassiz performed, but the value of a trained scientific imagination was most forcibly illustrated in his case.

The circumstances which led Agassiz to enter upon the study of paleichthyology were largely fortuitous. When a student at Heidelberg, being then scarcely twenty years of age, he attended a course of lectures on paleontology by Professor Bronn, a teacher of profound erudition, and for whom he always entertained feelings of the warmest regard. The first portions of Goldfuss's great work, *Petrefacta Germaniae*, were then just issuing from the press, and awakened a sensational interest in geology and paleontology. The highly fossiliferous rocks of southern Germany were eagerly searched by collectors, and large gatherings found their way into the principal museums. Munich in particular became the repository of those exquisitely preserved remains which have made the name of Solenhofen famous in the annals of paleontology for all time. And thither, to Munich, Agassiz came before he was twenty-one, yet not without having made the acquaintance of almost every large-sized collection in the land. To use his own words, as given in a brief account of his university life, "I knew every animal, living and fossil, in the Museums of Munich, Stuttgart, Tübingen, Erlangen, Würzburg, Carlsruhe, Heidelberg, and Frankfort."<sup>1</sup>

The project of preparing a general work on fossil ichthyology seems to have first taken shape in his mind while a student at Heidelberg; its feasibility was impressed upon him after an examination of the above-mentioned collections, and on receiving numerous friendly offers for the loan of specimens; and its initiation dates from the period of his removal to Munich, if we may judge from a letter written to his brother in January, 1830, from which we quote as follows:

Having by permission of the Director of the Museum one of the finest collections of fossils in Germany at my disposition, and being also allowed to take the specimens home as I need them, I have undertaken to publish the ichthyological part of the collection. Nowhere so well as here, where the Academy of Fine Arts brings together so many draughtsmen, could I have the same facility for completing a similar work; and as it is an entirely

<sup>1</sup> *Louis Agassiz, His Life and Correspondence*, by E. C. Agassiz. Boston, 1885. Vol. i, p. 157. On the growth of some of these institutions and the influence of Bronn and others, see an article by K. A. von Zittel, in *American Geologist*, vol. xiv, 1894, pp. 179-185.

new branch, in which no one has as yet done anything of importance, I feel sure of success; the more so because Cuvier, who alone could do it (for the simple reason that every one else has until now neglected the fishes), is not engaged upon it. . . . Now that I have it in my power to carry out the project, I should be a fool to let a chance escape me which certainly will not present itself a second time so favorably.

Three years after the date of this letter the first *livraison* of his immortal *Poissons Fossiles* appeared, the publication of which in five large quarto volumes, illustrated by nearly four hundred folio plates, extended over the interval from 1833 to 1844, and was followed by a supplementary volume, entitled *Monographie des Poissons Fossiles du Vieux Grès Rouge où Système Devonien* (*Old Red Sandstone*), with an atlas of thirty-three plates, in 1844-45.<sup>1</sup>

The author's work on this "vaste publication" was embarrassed by difficulties of the most aggravating nature. There were first of all the exacting terms imposed by his publisher, Cotta of Stuttgart, who eventually withdrew from the undertaking as being too expensive; and afterwards the financial hazard involved in the maintenance of a private printing establishment. The restrictions of many museum authorities relative to the transportation of specimens proved also a serious hindrance, necessitating as it did a journeying about on the part of himself and an artist until he had ransacked every collection worthy of the name in Europe. To say nothing of the personal expense and labor he was subjected to by this plan, it was unsatisfactory for yet another reason, to which he refers as follows in the preface to his *Poissons Fossiles*:

Notwithstanding the cordiality with which even the most precious specimens have been placed at my disposition, a serious inconvenience has resulted from this mode of working; namely, that I have rarely been able to compare directly the various specimens of the same species from different collections, and that I have often been obliged to make my identification from memory, or from simple notes, or, in the more fortunate cases, from my drawings alone. It is impossible to imagine the fatigue, the exhaustion of all the faculties, involved in such a method. The hurry of traveling, joined to the

<sup>1</sup> For the actual dates of publication of the various parts and plates, see the list compiled by W. H. Brown, and prefixed to the *Catalogue of British Fossil Vertebrata*, by A. S. Woodward and C. D. Sherborn (London, 1890), pp. xxv-xxix.

lack of the most ordinary facilities for observation, has not rendered my task more easy.

The incidents that befell him while prosecuting his researches; the friendships he formed with all the distinguished scientists of the day; the favorable impression he everywhere created, especially in Britain, where his fame had preceded him; the influence of Humboldt and Cuvier upon his career; his prodigious energy, enthusiasm, and devotion to his chosen purpose; the personal qualities drawn out by the struggles and hardships he endured; his gratification at the final acknowledgment of his success, — all these are topics which have been abundantly treated of by his biographers. It remains for us merely to call attention to some of the more general features of his work on paleichthyology. But here, too, it will be difficult at this day for one to offer anything novel, since during the last half-century it has been frequently and ably reviewed.

We can only add our tribute, in a word, that the publication of the *Poissons Fossiles* laid the foundation of a new science, and reared at the same time a large portion of its superstructure. This work also marked an epoch in the history of paleontology and zoology in general, since one of its brilliant results was the discovery of certain comprehensive laws, which are now admitted to be of fundamental importance. Without doubt the most far-reaching of these in its consequences is the analogy which he pointed out between the embryological phases of recent fishes and the geological succession of the class; whereupon he deduced the generalization, "The history of the individual is but the epitomized history of the race." Another notable result was the recognition and characterization of his so-called prophetic or synthetic types, that is, such as embrace features in their organization which afterwards become distributed among a number of groups, and are never recombined. Incidentally, or rather as a corollary to the preceding, he introduced a new method of studying animal types; namely, that of testing zoological results by embryological investigations, and, similarly, embryological by paleontological. He insisted that the comparative anatomy of a group, including its paleontological record, should be studied in connection with the comparative

embryology of the same; in fine, as he says, "The results of these two methods of inquiry complete and control each other."

In this memoir Agassiz also worked out the geological succession and distribution of the different groups of fishes, thereby greatly increasing the practical value of their remains as an aid in identifying strata. His observations upon the heterocercal tail, its duration in time, and, owing to accelerated development, its transitory appearance in the early stages of recent forms deserve notice in this connection. The principles of tachygenesis seem to have been fully grasped by him, although not distinctly formulated. To him properly belongs the credit, also, according to the testimony of one of his students at a later date,<sup>1</sup> of having first apprehended and expounded what is commonly called the biogenetic law of Haeckel.

Yet another important feature of the *Poissons Fossiles* was the proposal of an entirely new system of classification of fishes, fossil and living, based upon the different types of scales, which were found to coincide to a remarkable degree with certain skeletal differences. His system was the first to recognize the ganoids as an independent order, although it is true that the limits assigned it were much larger than we can at present allow. However, Agassiz did not himself overestimate the value of his classification, being fully aware of its empiric character; but he committed himself to it chiefly on account of its great practical convenience. His aim was quite as much to prove the succession of fossil fishes throughout the different geological horizons as to work out their anatomical structure; and for this purpose, as well as for enabling him to bring together in an intelligible order large quantities of fragmentary material, it succeeded admirably. It may not be amiss to cite in this connection a letter of his to Humboldt, in which he disclaims attaching any special importance to his classification, and con-

<sup>1</sup> Cf. Alpheus Hyatt, On Cycle in the Life of the Individual (Ontogeny), and in the Evolution of its Own Group (Phylogeny). *Science*, N.S., vol. v (1897), pp. 161-171. Hyatt considers that "Agassiz's introduction of the element of succession in time laid the basis for all more recent [embryological] work" (p. 163).

tinues as follows: "My object was only to utilize certain structural characters which frequently recur among fossil forms, and which *might therefore enable me to determine remains hitherto considered of little value.*"<sup>1</sup>

Lastly, the *Poissons Fossiles* is notable for still constituting the most valuable repository of information we have on fossil fishes. In it are enumerated more than one thousand species, the greater part of which are accurately described and magnificently illustrated; and it is worth recording that the first successful application of chromolithography was in the execution of these plates. The fidelity of the drawings to nature and the minuteness of the accompanying descriptions have never ceased to challenge wonder and admiration.

Passing now for a moment to Agassiz's supplementary volume on the *Fishes of the Old Red Sandstone*, one cannot but feel amazement at the accuracy, cleverness, and originality of the author as displayed throughout this truly wonderful work. Greater difficulties were encountered in the way of studying the remains, which were scanty at best and imperfectly preserved; and more intricate problems presented themselves respecting the anatomy and homology of parts than any he had met with in the preparation of his larger work. True, the discovery of the Ludlow and Cromarty faunas was not a matter of long standing, but it had already engaged the attention of the most eminent British geologists and paleontologists, who were one and all confounded over the problematical organisms. But whether as a result of his training or intuition, or both, Agassiz had no hesitation in declaring, the moment he examined one of Hugh Miller's drawings and description of *Pterichthys*, that the creature was a chordate, and belonged to the class of fishes. His astonishment, however, on first seeing the actual fossils, is well told by himself in the preface to his monograph, as follows:

I can never forget the impression produced upon me by the sight of these creatures, furnished with appendages resembling wings, yet belonging, as I had satisfied myself, to the class of fishes. . . . It is impossible to see aught more bizarre in all creation than the *Pterichthyan* genus; the same aston-

ishment that Cuvier felt in examining the Plesiosaurus I myself experienced when Mr. H. Miller, the first discoverer of these fossils, showed me the specimens which he had collected in the Old Red Sandstone of Cromarty.

Any one who has attempted for himself to decipher the distorted and for the most part obscure remains from the Scottish Old Red can imagine the difficulties which the first students of such extraordinary forms labored under. He will understand that above all scrupulous refinement of observation is necessary; that innumerable comparisons and attentive reëxaminations of even the most tattered fragments must be made in order to test his hypothesis of the association of parts. Considering the means at Agassiz's disposal, his work must be pronounced nothing short of brilliant; it was remarkable alike for the originality and insight displayed, and for the general correctness of his conclusions. That some of his generalizations should have been premature was an inevitable consequence of pioneer work. And if, after more than fifty years, certain of his views are found to require modification, or to be no longer tenable, what more was to have been expected?

To cite one or two instances by way of illustration, let us suppose we grant with Cope that the Ostracodermi are not fishes; properly speaking, but belong to a group at the base of the craniate Vertebrata, characterized by the lack of a lower jaw and of paired limbs; how does that detract any from the unerring judgment of Agassiz, who pronounced them first of all to be chordates, and assigned them a place among the most primitive of ganoids? If we criticise his restorations of *Pterichthys* and *Coccosteus* as being crude and fanciful, we cannot accuse him, at all events, of misrepresentation. Just as it required the genius of a Traquair after many years of patient study to prove that the *Platysomidæ* are in no sense whatsoever related to the pycnodonts,<sup>1</sup> so, too, it required the combined efforts of the best Russian, German, and British talent to unravel the complicated structure of the coccosteids and ostracoderms. Tremendous advances have since been made, almost as a matter of course, but it was Agassiz who first clearly

<sup>1</sup> R. H. Traquair, On the Structure and Affinities of the *Platysomidæ*. *Trans. Roy. Soc. Edinburgh*, vol. xxix, 1879, pp. 343-391.



pointed out the way. Again, if it be said that Agassiz created numerous species on too slender grounds of distinction, does not this merely express the refinement of his personal equation in the art of discerning differences between allied forms of organisms, for which compensation is easily possible?

Aside from the classic works just noticed, Agassiz contributed very little to the subject of paleichthyology. A few minor papers appeared in different journals, or were appended to geological monographs by other authors (Murchison, de Verneuil, Keyserling, etc.), prior to his departure for America. In this country his attention was so diverted in other directions that he was unable to prosecute further original investigation. Some informal reports on fossil fishes were prepared by him at the meetings of the American Association for the Advancement of Science (at one of which, the Cincinnati meeting, in 1851, he offered some surprising comments on *Macropetalichthys*), and brief notes on the fishes of the Virginia Coalfield were contributed to Lyell's account of the geology of the basin in 1847. With these exceptions, the only paper from his pen on fossil fishes in America is that appended to the fifth volume of the Pacific Railroad Surveys,<sup>1</sup> published in 1856. It is also rather remarkable that he succeeded in interesting only one student of his to take up this line of research seriously; this was Mr. Orestes St. John, well known from his writings on Carboniferous fishes from Illinois and other western states.

Many have wondered why Agassiz, with all his wealth of information, his fertility of imagination, and after having discovered the very laws which constitute so important a bulwark in the theory of evolution, should persistently have opposed that doctrine, although his work on fossil fishes prepared the way for it most admirably. There can be no doubt that his mind was closed to such conclusions through the influence of preconceived ideas, on which it is unnecessary for us to dwell. His position with reference to the evolutionary hypothesis has been

<sup>1</sup> Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean. *Report of Explorations in California*, by Lieut. R. S. Williamson, vol. v, Washington, 1856. (Abstract of Agassiz's article in *Amer. Journ. Sci.* [2], vol. xxi, 1856, p. 274.)

so fittingly summarized by Le Conte<sup>1</sup> that we cannot do better, in conclusion, than heartily to indorse the following sentiments:

“There is something to us supremely grand in this refusal of Agassiz to accept the theory of evolution. The opportunity to become a leader of modern thought, the foremost man of the country, was in his hands, and he refused, because his religious, or perhaps better, his philosophic intuitions forbade. . . . A lesser man would have seen less clearly the higher truth, and accepted the lower. A greater man would have risen above the age, and seen that there was no conflict [between the theory of descent and still more certain truth], and so accepted both.”

<sup>1</sup> Joseph Le Conte, *Evolution and its Relation to Religious Thought*, p. 45. New York, 1888.